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SYSTEMS ENGINEERING CAPSTONE PROJECT REPORT

DEVELOPMENT OF A SYSTEMS ENGINEERING COMPETENCY MODEL TOOL FOR THE AVIATION AND MISSILE RESEARCH, DEVELOPMENT, AND ENGINEERING CENTER (AMRDEC)

by

Mark Chess, Adam Christiansen, Daniel Cobb, Joseph Green, David Jerome, Brandon Payne, Mark Rusak, and Timothy Wright

June 2017

Project Advisor: Clifford Whitcomb
Second Reader: Ronald Carlson

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Mark Chess
Adam Christiansen
Daniel Cobb
Joseph Green
David Jerome
Brandon Payne
Mark Rusak
Timothy Wright

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Lead editor: David Jerome

Reviewed by:
Clifford Whitcomb
Project Advisor

Ronald Carlson
Second Reader

Accepted by:
Ronald Giachetti
Chair, Systems Engineering Department

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ABSTRACT

The Naval Postgraduate School has developed a competency model for the systems engineering profession and is implementing a tool to support “high stakes” human resource functions for the U.S. Army. A systems engineering career competency model (SECCM), recently developed by the Navy and verified by the Office of Personnel Management (OPM), defines the critical competencies for successful performance as a systems engineer at each general schedule grade level (GS-7 to GS-15). This foundational model is structured to support the individual needs of any Department of Defense organization and is made operable through the creation and implementation of tools to facilitate the management of systems engineering competencies at the local organizational level with traceability to the approved OPM competencies. The Redstone SECCM Tool will allow documentation of system engineering competencies and assessment of individual and organizational development and training needs. This report documents the requirements analysis, system design, and system verification of the Redstone SECCM Tool, providing a path for implementation of the SECCM to support systems engineering human resource actions.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACT	Army Career Tracker
AHP	Analytic Hierarchy Process
AMC	Army Materiel Command
AMRDEC	Aviation and Missile Research, Development, and Engineering Center
AoA	analysis of alternatives
AT&L	Acquisition, Technology, and Logistics
CFR	Code of Federal Regulations
CP-16	Career Program (Scientist and Engineer)
DAG	Defense Acquisition Guidebook
DASN	Deputy Assistant Secretary of the Navy
DAU	Defense Acquisition University
DCPAS	Defense Civilian Personnel Advisory System
DOD	Department of Defense
FMECA	Failure Mode, Effects, and Criticality Analysis
GAO	Government Accountability Office
GS	General Schedule
HCD	Human Centered Design
HR	human resources
IAW	in accordance with
INCOSE	International Council on Systems Engineering
IRB	Institutional Review Board
ISO	International Organization for Standardization
ITEA	International Test and Evaluation Association
MDA	Missile Defense Agency
MOSAIC	Multipurpose Systems Analysis Inventory - Close Ended
MVP	Minimum Viable Product
NPS	Naval Postgraduate School
ODASD(SE)	Office of the Deputy Assistant Secretary of Defense (Systems Engineering)

OPM	Office of Personnel Management
PEO M&S	Program Executive Office for Missiles and Space
PMP	Project Management Plan
RAM	Reliability, Availability, and Maintainability
RDECOM	Research, Development, and Engineering Command
RDTE	Research, Development, Test, and Evaluation
SE	systems engineering
SECCM	Systems Engineering Career Competency Model
SED	Software Engineering Directorate
SME	subject matter expert
TBD	to be determined
USC	United States Code

EXECUTIVE SUMMARY

The Office of Personnel Management, with the assistance of the Naval Postgraduate School (NPS), developed a Systems Engineering Career Competency Model (SECCM) to meet the competency-based workforce management needs of the Department of Defense. A verified SECCM would assist in "high-stakes" human resource functions such as position description creation, selection, and promotion, as well as employee development. The SECCM is now the foundational competency model that any defense agency can use to describe work functions and competencies for the proficient execution of systems engineering functions. In order to maximize the utility of this document, NPS tasked a capstone group to explore the application of this SECCM at the organizational level. The capstone team chose to conduct the effort using a modified system engineering life cycle including a Stakeholder Needs and Requirements Definition process, a Design Definition process, and a System Verification process.

The Stakeholder Needs and Requirements Definition process started by identifying relevant stakeholders. The stakeholders for this task include human resources departments, hiring managers, engineering supervisors of systems engineers, and systems engineering employees. A diverse set of stakeholders were identified across Aviation and Missile Research, Development, and Engineering Command (AMRDEC) who displayed a knowledge of systems engineering as well as a need for assistance in systems engineering career development or hiring-manager functions. Each stakeholder participated in an Institutional Review Board (IRB)–approved interview session intended to define the competency development needs.

Once the data was gathered from the interviews, the capstone team used a Human Centered Design (HCD) method for interpretation and need definition. The capstone team transferred data to Post-it notes and sorted through answers to find common themes. From the data, the current state of the systems engineering career field is inconsistent, consisting of variations between services, training, and even between organizations. Different user personas were developed to identify potential users of the SECCM and aid

in identifying the underlying needs from the user feedback. A set of stakeholder needs was identified from the analysis, with the emphasis of this effort on

- a need to refocus SE competencies from 44 to SE specific competencies and
- a need for an adaptable career competency model that can be defined and managed locally at the organization level.

The final step in the Stakeholder Needs and Requirements Definition process consisted of translating the stakeholder needs into actionable requirements. Using a brainstorming process that included affinity diagrams and trend analysis, a set of three primary requirements and three subordinate requirements were defined and utilized as the basis for the project.

The Design Definition process began with alternative definition and selection. Multiple alternatives were considered to meet the stakeholder needs, including a user guide, custom software, a spreadsheet implementation, and a mobile phone app. Each design solution was intended to implement the SECCM into a more user-friendly product that could be tailored at the local level. The Analytic Hierarchy Process (AHP) was chosen as the method to complete an analysis of alternatives (AoA). Each alternative was weighed against three factors: ease of use, completeness of meeting all the requirements, and implementation time. After weighing each alternative against the three factors, a combination of the user guide and spreadsheet was chosen, which met the most requirements in the timeframe allowed.

The spreadsheet solution, also called the Redstone SECCM Tool after the location of the capstone team, gives the user a step-by-step walkthrough on how to develop a local competency model. Each competency can have up to six user-defined proficiency levels and can be tied to the Army SECCM for “high-risk” human resource functions. After completion of the competency model, the model can be assigned to an individual employee to track the employee’s personal competency development. The user guide solution, now called the Redstone Systems Engineering Career Competency Model Tool User Guide, gives a step-by-step procedure on developing a competency model within the Redstone SECCM Tool and is a companion product to the tool.

The final step in the system engineering life cycle was the System Verification process. The stakeholders were once again asked a set of IRB-approved questions, this time on the quality of the tool and user guide. At the time of the event, the user guide had not yet been completed and therefore was not rated. The tool was given high ratings on most areas including meeting expectations, overall satisfaction, ease of use, and tailorability. After the verification event with the stakeholders was completed, metrics were an additional functionality added to the Redstone SECCM Tool. Metrics can now be tracked on all users of a single competency model within an organization to track organizational growth. Additional capabilities were identified but were unable to make it into the final version of the tool. These capabilities were included as a set of future recommendations for the tool, including as follows:

- “Required at Entry” and “Important” discriminators among the competencies
- weighting factors
- a notes column
- printable reports
- historical progression tracking
- additional graphing capability
- tracking for specific positions or domains

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I. INTRODUCTION

The need for qualified systems engineers within the DOD has been growing for many years. As the complexity of DOD systems evolves, so must the knowledge, skills, and abilities of systems engineers tasked with managing and directing complex systems in all stages of their life cycle (Government Accountability Office [GAO] 2015). This need is further reinforced by the publicity surrounding large program-cost overruns, coupled with the impacts of an ever-increasing number of failed programs (GAO 2014). These situations highlight the expanding need for properly trained, competent system engineers across the DOD.

The Office of the Deputy Assistant Secretary of Defense for Systems Engineering (ODASD(SE)) is the focal point for increasing the development and use of organic systems engineering (SE) processes across the DOD (Under Secretary of Defense for Acquisition, Technology and Logistics [AT&L] 2011). The ODASD(SE) is aggressively working to address a range of engineering challenges presented by the increasing complexity of emerging weapons systems (International Test and Evaluation Association [ITEA] 2016). The development of organic SE workforce competencies within the DOD is a crucial initiative needed "to improve engineering, test, and evaluation methods and tools; and to broaden its partnerships with commercial and defense industry, universities, and federally funded research and development centers that augment organic capabilities with critical talent" (ITEA 2016). To make significant progress in workforce development, the DOD still has work to do in order to define and develop many new areas for systems engineers, such as workforce training for requirements development and resource trade-offs (GAO 2015).

The Department of Defense (DOD) utilizes a competency-based approach for workforce management (U.S. Office of Personnel Management [OPM] 2016a). This approach requires that the DOD assess the critical skills and competencies needed for its workforce both in the short and long term. The DOD must also plan and execute strategies for closing competency and skill gaps.

For the SE field, one method for executing this strategy in the long term is to create an SE occupational series code, which is currently nonexistent within the OPM's Position Classification Standards (OPM 2009). Given that the classification of positions for employees within government organizations is mandated under Title 5 of the United States Code (USC), this particular option has far-reaching implications. For short-term execution, the DOD has the option of using a competency model verified for "high stakes" Human Resource (HR) functions (Whitcomb et al. 2015; Khan et al. 2016). "High stakes" HR functions, such as selection, position description creation, and promotion require the use of a competency model verified in accordance with (IAW) the Uniform Guidelines on Employee Selection Procedures, mandated under Title 29 of the Code of Federal Regulation (CFR). These Uniform Guidelines are a set of Federal laws and standards designed to assist employers, labor organizations, employment agencies and licensing/certification boards in complying with requirements that prohibit discriminatory employment practices (White et al. 2016). The lack of an occupational series for SE meant that the SE discipline did not have an existing competency model that could be used to meet the strategic implementation needed for either the long-term or short-term options.

To help address the gap of a missing competency model for the SE field that would align with both the USC and CFR, the Deputy Assistant Secretary of the Navy (DASN) for Research Development Test and Evaluation (RDTE) tasked the Naval Postgraduate School (NPS) with researching the SE discipline and developing a SE competency model for defense (OPM 2016a). This effort included research into existing SE functions and surveys of current systems engineers. The Systems Engineering Career Competency Model (SECCM) is the product of this DASN RDT&E sponsored effort between NPS and the OPM.

Due to the importance of verifying a competency model for use in "high stakes" HR functions, the OPM conducted an effort to verify SE core competencies IAW the Uniform Guidelines. The OPM utilized its Multipurpose Occupational Systems Analysis Inventory-Close-Ended (MOSAIC) methodology to verify the SECCM (White et al. 2015). Through the MOSAIC process, the OPM facilitated a series of Subject Matter

Expert (SME) panels to create a list of competencies and tasks to use as the basis for an Occupational Analysis Survey. The survey was given to a sample of the SE population across the Army, Navy, Air Force, and Missile Defense Agency (MDA). After receiving and analyzing the results, the OPM identified critical competencies and tasks for DOD systems engineers (OPM 2016a).

The SECCM is now the foundational competency model that any defense agency, such as the U.S. Army, U.S. Air Force, or U.S. Navy, can use as a resource to meet individual organizational needs, describing competencies and related work tasks needed for the proficient execution of SE job functions. The SECCM identifies critical competencies and tasks for systems engineers within the General Schedule (GS) pay grades, at the GS-07 to GS-15 grade levels. The SECCM can be tied directly to the USA Staffing Competency Network, assisting hiring managers in developing position descriptions and hiring actions (Defense Civilian Personnel Advisory System [DCPAS] 2017).

An NPS capstone project was organized to develop further a method for implementing the SECCM within an organization. A group of students, colloquially referred to as "Team Redstone," within the NPS Systems Engineering Master's Program selected this topic for their capstone project. The OPM survey analysis and technical report for the U.S. Army was provided as a reference source for Team Redstone (OPM 2016b), to develop an SE competency model implementation for the Aviation and Missile Research, Development, and Engineering Center (AMRDEC). This capstone project report presents the development process and the findings for this effort.

A. PROBLEM STATEMENT

The DOD SE field does not have an occupational series, leading to local organization variations in both the definitions and expectations of competencies for systems engineers (White et al. 2016). According to White et al. (2016), without a defined competency model for systems engineers that has been verified IAW Uniform Guidelines, there can be no consistency across DOD in creating position descriptions, assessing job candidates, hiring, providing a basis for employee performance, and

establishing career path models and associated development plans for SEs. Now that an OPM-validated competency model has been developed at the Army level, the need shifts to identifying how best to implement the SECCM locally in organizations and divisions that utilize SEs. The SECCM is a broad document that covers SE at the Army level and must be applied at the organizational level in order to reap the maximum benefit.

B. PROJECT APPROACH

This project is focused on the application of the SECCM for the Army, in particular the Army's Aviation and Missile Research, Development, and Engineering Center (AMRDEC). Stakeholders were identified to represent all the aspects of SE career competencies, and the stakeholder feedback and responses steered the project direction. These responses formulated what would become the needs and requirements of the project.

The capstone team used a project management approach to the product development. This is documented as the Team Redstone Project Management Plan (PMP). The PMP is a formal document that describes how the project was managed, controlled, and executed during the project life cycle. The PMP contains the overarching guidance, procedures, schedules, and methods used for planning, monitoring, and controlling the overall project.

C. REPORT ORGANIZATION

This report is laid out based on Team Redstone's tasks, which were centered on an SE life-cycle model approach. This approach was then tailored to the specific needs and challenges of the project. The sections of the report are:

Chapter I, Introduction – Provides a background and problem statement to frame the project.

Chapter II, Stakeholder Needs and Requirements Definition – Provides a detailed analysis of the stakeholder identification, needs analysis and results, and derived stakeholder requirements.

Chapter III, Design Definition – Provides an analysis of alternatives for potential design solutions and an explanation of the selected design solution.

Chapter IV, System Verification – Provides a description of the verification effort associated with the selected design.

Chapter V, Summary, Conclusions and Recommendations – Provides a summary of the problem, how the design solution was able to address the stakeholder needs, and the overall conclusions from the project effort, and a list of forward-looking recommendations to address other stakeholder needs.

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II. STAKEHOLDER NEEDS AND REQUIREMENTS DEFINITION

The foundation for implementing an SE process is a properly defined set of user needs. According to the International Council on Systems Engineering (INCOSE) Handbook, "Successful projects depend on meeting the needs and requirements of the stakeholders throughout the life cycle" (INCOSE 2015). The first step in the capstone project systems development process was the Stakeholder Needs and Requirements Definition process. Stakeholder needs definition was conducted to identify stakeholders, gather their needs, and analyze the information to determine their true needs to be used as a basis for the project developments. Often, there is also a discovery process that takes place over time to adequately understand the true needs of each stakeholder. To reduce the discovery time, the Human Centered Design (HCD) approach was used to ensure that stakeholders are involved in all phases of the design, that needs are adequately characterized, and that requirements are developed to meet the needs of the users. For this project, the Army SECCM was used as a point of reference to start the discovery process. This chapter discusses stakeholder identification, the HCD approach used to elicit accurate stakeholder needs, stakeholder needs analysis and results, and the feedback loop that resulted in a final set of stakeholder requirements based on the assessed needs.

A. STAKEHOLDER AND NEEDS IDENTIFICATION

The stakeholders for this task include human resources (HR), hiring managers, engineering supervisors who manage the daily tasking of systems engineers, and SE employees. The scientist and engineer career program (CP-16) proponency office within the Army Materiel Command (AMC) also served as a stakeholder, given its mission to develop career engineers. The CP-16 proponency office develops career plans and offers funding for career training, as well as project office personnel who manage the matrixed systems engineers, relying on their support to successfully field systems. Each of these stakeholders has some experience with the challenge of developing training plans, hiring, developing job descriptions, and defining career paths used by their employees to build competencies in SE.

Each identified stakeholder offers a unique perspective on the roles that systems engineers take within the Army as well as the necessary skills, training, and competencies expected. Each stakeholder participated in an interview session with open-ended questions intended to gain an understanding of their unique perspectives on SE within the DOD. Stakeholder identification was based on feedback from within each group members' organization. In order to develop an Army SE competency model, stakeholders within AMRDEC, AMC, Program Executive Office Missiles and Space (PEO M&S), and Software Engineering Directorate (SED) were identified to provide a diverse perspective of the needs, capabilities, and shortcomings of tracking and understanding SE competencies within the Army. Each stakeholder is in a leadership position within his or her respective organization and each has expressed a sincere interest in furthering the development of an SE competency model. The power interest grid, shown in Figure 1, was used to assess the level of influence shared among the selected stakeholders.

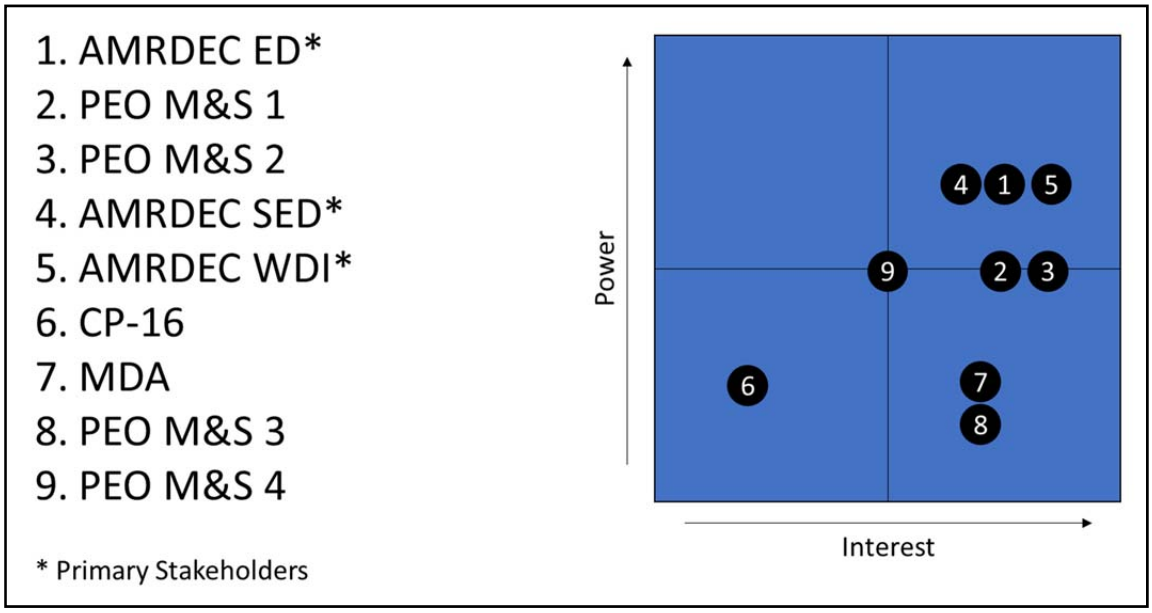

Figure 1. Power Interest Grid

The project took an interpretive, qualitative approach to identifying and understanding stakeholder needs based on a predetermined set of interview questions. These interview questions were developed with the purpose of finding objective areas of

need based on identified issues and gaps that exist for SE within the Army. The NPS Institutional Review Board (IRB) determined that the interview questions were not human-subjects research. The questions, along with a copy of the OPM "Army Systems Engineering Occupational Analysis," were given in advance of the interviews to allow the stakeholders time to review the background information and make connections to the questions. Two members of the capstone project team conducted each interview; one team member served as the interviewer and the other assisted the interviewer by verifying that all of the questions were discussed and recording the stakeholder statements made during the interview. Interview notes are available in the appendix.

B. HUMAN-CENTERED DESIGN APPROACH

The standard SE approach was modified by integrating HCD methods. Detailed information relative to the human-system interactions that occur throughout the life cycle is given in the technical specification "Ergonomics of Human-System Interaction—Specification for the Process Assessment of Human-System Issues" (International Organization for Standardization [ISO] TS 18152 2010), while specific requirements and guidance relating to HCD are provided in the international standard "Human-centered design for interactive systems" (ISO 9241-210 2010). These documents help address human-centered issues that arise throughout a system life-cycle process and provide a human-centered perspective that is complementary to existing SE development process methodologies. Because HCD "is a creative approach to interactive systems development that aims to make systems usable and useful" (ISO 9241-210 2010), HCD forces the designer to empathize with the user and to help understand the needs while also creating a design that provides personal appeal. When done properly, a human-centered approach "fuels the creation of a product that resonates more deeply with an audience" (Thomsen 2013). To gain greater contextual perspective on the stakeholders needs and work through to a solution, the capstone team performed HCD activities similar to those presented by IDEO (IDEO 2015).

The HCD method adopted for this project follows an approach that aligns with technical life-cycle processes identified in ISO 15288 as stakeholder requirements

definition, requirements analysis, architecture, design, implementation, integration, verification, transition, validation, operation, maintenance, and disposal (ISO 15288 2015). The HCD stages that complement these processes include framing the problem, exploring the problem space, designing a solution through ideation and iteration, discovering or redefining the solution based on prototyping and feedback, and delivering the solution. The specific HCD steps and their comparable generic technical processes, as described in ISO 15288, are shown in Table 1.

Table 1. HCD Stages

HCD Stages	**Comparable Technical Processes (ISO 15288)**
Frame	Stakeholder Requirements Definition
Explore	Analyze System Requirements
Design	Define Architecture
Discover	Design Architecture
Deliver	Implementation, Integration, Verification, Transition, and Validation

Following these steps allowed for the explicit understanding of stakeholder needs by involving them throughout the entire developmental process. By employing an HCD methodology, the capstone team was able to view needs from the perspectives of the stakeholders while gathering critical information helpful in solving problems or issues exposed during this project.

By working through the problem framing, exploration, ideation, iteration, and discovery stages, the capstone team was able to take a HCD approach toward the processes involved in the creation of the SECCM. For example, rather than attempting to define each of the OPM SE competencies and include the entire set in the solution presented to stakeholders, the HCD design thinking approach resulted in questions that resonated with the stakeholders, such as “How does SE benefit the stakeholders

organization?" and "What specific competencies are required to be an effective systems engineer?."

Three issues discovered during this project revealed how HCD strategies were used to formulate effective mitigation strategies:

Issue 1: Currently, there is no way to ensure that the stakeholders identified represent a large percentage of the SE population within Army or even across the organizations identified in this report.

Mitigation strategy: The capstone team sought to overcome this by developing an adaptable and tailorable solution that is able to meet the needs of users not represented by the stakeholders selected for this project.

Issue 2: The stakeholder questions may not have been designed correctly or do not clearly identify higher-level needs within the Army SE workforce.

Mitigation strategy: By producing minimum viable products (MVP) that address the largest assumptions first and release to a small test audience (e.g., beta testing, smoke testing), additional insights can be gained. Further iterating and testing design alternatives based on these lessons learned will help to identify any higher level needs not addressed early on.

Issue 3: There is risk associated with transcribing information from an interview, including loss of key points, lack of detail, and over-emphasis of nonessential information.

Mitigation strategy: This is addressed in part by keeping an "open line of communication" with each stakeholder throughout the project to obtain additional feedback and clarification as needed to help further iterate to the proper solution.

C. STAKEHOLDER NEEDS ANALYSIS

The capstone team began framing the problem by capturing and characterizing stakeholder inputs. By transferring interview information to Post-it notes, the team was able to reduce the information to smaller bites for useful visual representation. The Post-it notes that captured each interview's major points also listed the major takeaways from

each of the interviews. After correlating and sorting the information, the capstone team summarized the major points, presented in Table 2. Each cell represents an individual stakeholder's input.

Table 2. Major Interview Points

Major Points
• Competencies 1 – 19 are major SE competencies • All project offices act different • Need SE degree • SE upfront in the life cycle is most important
• Need breadth and depth of experience • Need training AND experience • The government does not do SE • The government poorly performs in requirements engineering
• Defense Acquisition University (DAU) training is a good start, but not enough • On-the-job training (with mentor) is required • Demonstrate experience • Focus on skill set, not knowledge, then apply it. • Model small project success
• Technical competence is most important • System experience as a whole • Breadth, depth in one area • On the job training, rotations • Aim at a job (ex. division chief), take the example and follow

Major Points
• Locally managed competencies • Competencies are NOT binary • Need experience • No SE job series needed
• Competency relevance to RDECOM • Army Career Tracker (ACT) training • Rotational training • Experience development
• A systems engineer is a subject-matter expert • Experience (breadth) • Experience depth first • Locally managed • Understand the entire life cycle • Define level of experience per grade
• Need more training for leadership skills • On-the-job experience • Competency model will be helpful

The capstone team then considered the differing viewpoints of the stakeholders as not every stakeholder defined a systems engineer in the same way. This was critical in defining and organizing the feedback. The outcome of this analysis allowed the capstone team to apply a filter to the stakeholders' feedback.

From the stakeholder feedback, OPM SECCM Report, and research of other existing competency models, the capstone team identified five characteristics that define the current state of the SE career field. Table 3 shows the current state.

Table 3. SE Current State

Ill-defined
Inconsistent
Large variation from organization to organization
Variation in training requirements
Differences among services (Army, Navy, Commercial, etc.)

Given the findings, the capstone team considered the current state of the SE career field to be ill-defined as more than a few of the OPM competencies were applicable to more than just systems engineers. The very definition of what a systems engineer is or does varies tremendously, even at local and organizational levels. To work toward correcting these issues with an end goal in mind, the capstone team proposes an "ideal" future state, as shown in Table 4.

Table 4. SE Future State

Competency model exists and is used regularly
Consistent definitions (skill sets, experience, etc.) exist and are referred to regularly
Job series descriptions exist and are referenced to regularly
Marketable skills/capabilities are developed in systems engineers
Career paths (institutional training, on the job training, DAU, mentoring, ACT, etc.) exist and are used regularly

Finally, the capstone team documented all of the potential users of the SECCM and developed user personas to ensure consideration was distributed appropriately, shown in Table 5. A persona is simply a fictional representation of real users or stakeholders that might interact with the system or process, utilized with intention of focusing on the users within the HCD process. These personas try to capture as many use-cases as possible while still remaining relevant to the problem at hand.

Table 5. User Personas

Entry-level engineer
Entry-level systems engineer
Current systems engineer
Candidate systems engineer
Systems engineering director
Human resources
Hiring managers

Once all of this information was considered, the capstone team met again solely to discuss all of the user persona information and develop the stakeholder needs.

D. STAKEHOLDER NEEDS ANALYSIS RESULTS

Using the combined *INCOSE Systems Engineering Handbook*, 4th edition, and HCD methods, individual replies from the stakeholders were grouped and categorized into similar needs based on affinity. As the capstone team uncovered common stakeholder interests, those items were refined and grouped to become stakeholder needs. Just as the stakeholder roles ranged from HR Management to SE practitioners, the replies received from the 17 questions varied in different topic areas and conclusions. The replies were reviewed and analyzed for any common issues or gaps. Some individual replies from the stakeholders have specific recommendations that can be used at the

requirements level. Those details are documented and archived for use later in the SE process. The capstone team analyzed the individual replies, concluding with a summarized list of stakeholder need statements as shown in Table 6.

Table 6. Stakeholder Needs

Need Index	Needs
N 1	A single, agreeable definition for SE within the Army
N 2	Need to condense SECCM-listed competencies from 44 to those specific to SE.
N 3	Need an adaptable career competency model that can be defined and managed locally at the organizational level.
N 4	Need training, experience, and education that encompass all phases of the system life cycle.
N 4.1	Need a comprehensive list of on-the-job training that would strengthen the competencies of Army systems engineers.
N 4.2	Need rotational assignments for systems engineers
N5	Need additional research to determine the benefit and feasibility of an SE job series.

E. STAKEHOLDER REQUIREMENTS DEVELOPMENT

A successful project depends on the ability of the SE team to translate the needs of the user into objective, demonstrable requirements. The purpose of the Stakeholder Needs and Requirements Definition Process as stated by INCOSE is to "define stakeholder requirements for a system that can provide the capabilities needed by users and other stakeholders in a defined environment" (INCOSE 2015). With stakeholder needs defined, a set of stakeholder requirements must be developed that

- are intended to meet the stakeholder need(s),
- clearly and concisely meet all parts of the need(s), and

- do not add capability outside of the need(s).

In this early stage of requirements development, gathering input and defining the process are the two most important steps in developing the stakeholder requirements. By gathering input through direct interviews, the capstone team was able to view needs from the perspectives of each of the stakeholders. Once the stakeholder needs, the system life cycle, and problem statement were defined, the capstone team focused on utilizing techniques similar to the HCD ideation and iteration processes to transform stakeholder needs into requirements. The capstone team conducted brainstorming sessions to decompose needs into requirements that involved clustering of information into uniquely characterized groups (or buckets) to highlight key stakeholder needs. Trends within the needs were identified using affinity diagrams and primary needs were identified by these trends, with an influence factor relating to the stakeholder's power versus their interest. By utilizing the power-interest grid in Figure 1, the capstone team was able to rank stakeholders based on their SE experience level and expected usage of the SECCM. Although many needs and subsequent requirements were identified during these processes, several were determined to be out of scope for this project based upon the capability limitations of the capstone team or project time constraints. Additional brainstorming conducted by the capstone team assessed select needs against candidate solutions and applicable verification methods, finding stakeholder needs N2 and N3, as defined in Table 6, to be within the scope of this project. The critical stakeholder needs identified during this phase were transformed into stakeholder requirements, as shown in Table 7, leading to key drivers to support the design phase of the capstone project. These requirements drove the design and development of a SECCM tool and user guide with the intended function to support the development of personnel and the tracking of organizational competencies. The design definition (selection and discovery) process is presented in Design Definition, Chapter III.

Table 7. Requirements Definition

Need Index	Requirement Index	Requirement
N1	**Out of scope**	
N2	R1	The competency model shall be limited to or segregated by system engineering specific competencies as defined by Defense Acquisition Guide (DAG) Chapter 4 and INCOSE handbook.
N3	R2	The in-use competency model shall be managed locally.
	R2.1	The competency model shall provide measures to objectively scale progress.
	R2.1.1	The measures shall be based on objective experience within that competency.
	R2.1.2	The competency model shall define proficiency levels that indicate progress from lower to higher grade levels
	R3	The competency model shall be tailorable at the organizational level and below.
N4	**Out of scope**	
N4.1	**Out of scope**	
N4.2	**Out of scope**	
N5	**Out of scope**	

III. DESIGN DEFINITION

The Design Definition process, the second step in the capstone project systems development process, began once the capstone team felt confident that the requirements were objective and met the users' needs. The purpose of the Design Definition Process according to INCOSE is to "develop, express, document, and communicate the realization of the architecture of the system through a complete set of design characteristics described in a form suitable for implementation" (INCOSE 2015). Design characteristics and design enablers related to each user-defined requirement are developed. From this set of characteristics and enablers, different design alternatives are brainstormed and assessed. The most appropriate alternative is then selected. The details of these design phases are presented in the following sections, including identification of alternatives, analysis of those alternatives within the project scope, summary of the results and conclusions from the analysis of alternatives, and description of the final design selected.

A. ALTERNATIVES

Four alternative solutions were analyzed during this project and are described below:

User guide – The first solution analyzed was a user guide and its purpose is to explain to a user how to translate the SECCM into a competency model specific to the user. The guide would be constructed such that a user could use it to completely understand the SE specific competencies and the more general competencies found in the SECCM and how to apply those competencies to their own organization. In order to keep this document from growing beyond the scope of the capstone project, the users are assumed to have a basic understanding of SE processes and competencies.

Custom software – The second solution analyzed was a custom software program built from the ground up, which would create a local competency for the user. This software program would allow the user to create a local competency model derived from the SECCM. The software should be developed to be as user-friendly as possible in order

to reduce the user's required knowledge of the SECCM. This solution requires that each competency be traced from a user's competency to all applicable SECCM competencies.

Spreadsheet – The third analyzed solution was a semi-automated spreadsheet to allow the user to create a set of local competencies based upon simple inputs. The spreadsheet would include "tool tip" type explanations of each step, and allow the user to create competencies with the necessary information at each step. This spreadsheet would be created in an existing, well-known program such as Microsoft Excel or Access in order to lower the coding time required and increase user familiarity with the interface.

Mobile phone app – The final analyzed solution was a software application suitable for mobile phone usage. This app would allow an individual user to generate a competency model in a controlled environment but create a final product similar to the spreadsheet implementation. The app would require user input for the local competency while automatically generating the final competency product in the app. A competency model app example is the Naval Air Systems Command (NAVAIR) Career Guide Book available through the Apple app store.

B. ANALYSIS OF ALTERNATIVES

The analysis of alternatives (AoA) is an analytical process used to determine the solution that best meets the needs of the stakeholders. Also in consideration for this AoA is the time constraint of a solution that is achievable in the timeframe of a capstone project.

The Analytic Hierarchy Process (AHP) was used to analytically compare the different alternatives to each other to determine the best solution to the user needs. The AHP consists of three steps using the alternatives and selection criteria outlined below (Goodwin and Wright 2014, 75–77). These steps provide a normalized result, which indicates the preference of each alternative relative to the others. A higher value means that that alternative meets more of the solution criteria than alternatives with a lower value. All relative comparisons for weighting were done according to the values shown in Table 8.

Table 8. Weighting Values

Weighting Criteria	Value
Similar importance	1
Weakly more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9

Each set of factors (in this case either the alternatives or the selection criteria) to be compared were placed in a matrix. The comparisons were performed row to column, meaning if the factor in the row was more important than the factor in the column, the corresponding value shown in Table 8 was entered. If the factor in the row was less important than the factor in the column, the inverse of the number given in Table 8 was entered. A priority vector was then calculated by normalizing for each factor by column total and then taking the average of each row.

Selection criteria was defined using the AHP to select from the alternative to identify the final preferred solution. The following selection criteria was used to determine the final product output of the AoA:

- Ease of use – The ease of use criteria is a determination of the ability for each user to utilize the solution to create the end product that meets the user needs.
- Completeness – The completeness criteria is a determination of how many of the user needs the alternative will satisfy.
- Implementation time – The implementation time is a determination of the ability for the alternative to be implemented in the time allotted for the capstone project.

In the first step of the process, each of the selection criteria was weighted against each other to determine the level of dominance of one criterion over another in a matrix format. The “criteria” priority vector calculated for this matrix gives an understanding of the criteria which will have the highest impact on the analysis.

Next, each of the alternatives' selection criteria was weighed against each other for a single selection criterion. This yields one matrix per selection criteria. The "alternative" priority vectors for these matrices show which alternative more strongly meets each criterion. Finally, each "alternative" priority vector was multiplied by the "criteria" priority vector for each criterion analyzed in the first step. The priority vectors were summed for each alternative to calculate the final total for each alternative. The alternative with the highest value best meets the criteria.

Numbers above one (1) indicated that the item in the row was dominant to the item in the column. Numbers below one (1) indicated the item in the column dominated the item in the row. These were normalized, and then a priority vector was calculated to determine the relative weight of each selection criteria as shown in Table 9. The priority vector for all weighted comparisons was calculated by taking the relative weighting in each cell and dividing by the sum of the column. This is the new cell value. Then, these cell values are added to get the priority vector.

Table 9. Weighted Comparison for AoA Selection Criteria

	Ease of Use	**Completeness**	**Implementation Time**	**Priority Vector**
Ease of Use	1.00	0.20	0.33	0.12
Completeness	5.00	1.00	0.20	0.28
Implementation Time	3.00	5.00	1.00	0.60

The implementation time was evaluated to be approximately 60% of the total for the selection criteria. This means that the majority of the weight of the selection criteria was whether the alternative could be completed in the time allotted. Approximately a quarter of the weight was the capability of the alternative to meet the user needs, and the remaining 12% of the weight was given to the ease of use of the alternative.

Next, each criterion was evaluated independently by the alternatives. For each criterion, the capstone team determined the strength of importance for the alternatives against each other. These values were ranked according to the weighted values given, with separate comparisons made for the ease of use criteria as shown in Table 10.

Table 10. Weighted Comparison of Alternatives for Ease of Use

Ease of Use	**User Guide**	**Custom Software**	**Spreadsheet**	**Mobile App**	**Priority Vector**
User Guide	1.00	0.14	0.20	0.33	0.05
Custom Software	7.00	1.00	3.00	0.33	0.35
Spreadsheet	5.00	0.33	1.00	5.00	0.34
Mobile App	3.00	3.00	0.20	1.00	0.26

The analysis showed that the user guide was the lowest-rated alternative for ease of use, not being rated higher than any other alternative. The custom software and spreadsheet were rated equal to each other and more useful than the app. The results of this analysis support this conclusion. Review of the priority vector column showed that the custom software and spreadsheet were approximately equal in meeting the ease of use criteria.

Table 11 shows that the mobile app was rated the lowest for completeness, while the user guide was rated higher than any other criteria. This was supported by the priority vector, which showed the user guide as being twice as likely to meet the completeness criteria as the next highest alternative, custom software.

Table 11. Weighted Comparison of Alternatives for Completeness.

Completeness	User Guide	Custom Software	Spreadsheet	Mobile App	Priority Vector
User Guide	1	3	3	9	0.52
Custom Software	0.33	1	3	5	0.27
Spreadsheet	0.33	0.33	1	5	0.16
Mobile App	0.11	0.2	0.2	1	0.05

Table 12 shows that the custom software was rated lowest for the implementation time criteria. The mobile app was also rated low, beating only the custom software. Again, the priority vector bears this out, with custom software very low on the rating to meet this criteria, with the spreadsheet highest and the user guide next.

Table 12. Weighted Comparison of Alternatives for Implementation Time

Implementation Time	User Guide	Custom Software	Spreadsheet	Mobile App	Priority Vector
User Guide	1.00	3.00	3.00	0.33	0.29
Custom Software	0.33	1.00	0.14	0.33	0.06
Spreadsheet	0.33	7.00	1.00	5.00	0.39
Mobile App	3.00	3.00	0.20	1.00	0.26

C. AOA RESULTS

The priority vectors for each alternative were combined into the final results shown in Table 13. The user guide and spreadsheet options were nearly identical in their final weighted result based upon the analysis. The mobile app and custom software were well behind the top two in ability to meet the specified selection criteria.

Table 13. Analysis of Alternatives Results

User Guide	Custom Software	Spreadsheet	Mobile App
0.33	0.15	0.32	0.20

D. AOA CONCLUSIONS

The AHP revealed that the spreadsheet and user guide solutions were very closely weighted in terms of the selection criteria. Based upon this result, a hybrid approach was selected that combined a spreadsheet solution (to guide users to the creation of their own local competency model) with the deeper explanation and definition provided by the user guide. To accomplish the hybrid solution, the user guide was tailored to the usage of the spreadsheet and not to the SECCM exclusively.

E. DESIGN SOLUTION

A Microsoft Excel–based SECCM tool, named Redstone SECCM Tool, along with a user guide, was selected as the design solution that would most efficiently meet the stakeholder needs. The tool provides a wizard-based, user-friendly interface for creating competency models that are intended to be traceable back to the OPM SECCM competencies. The tool provides flexibility by allowing the user to either generate organizational models for dissemination or develop employee competency models. The employee models can be used within the local organizations for developing training plans. The Welcome Menu, shown in Figure 2, provides primary entry points for using the tool to create or update the competency models.

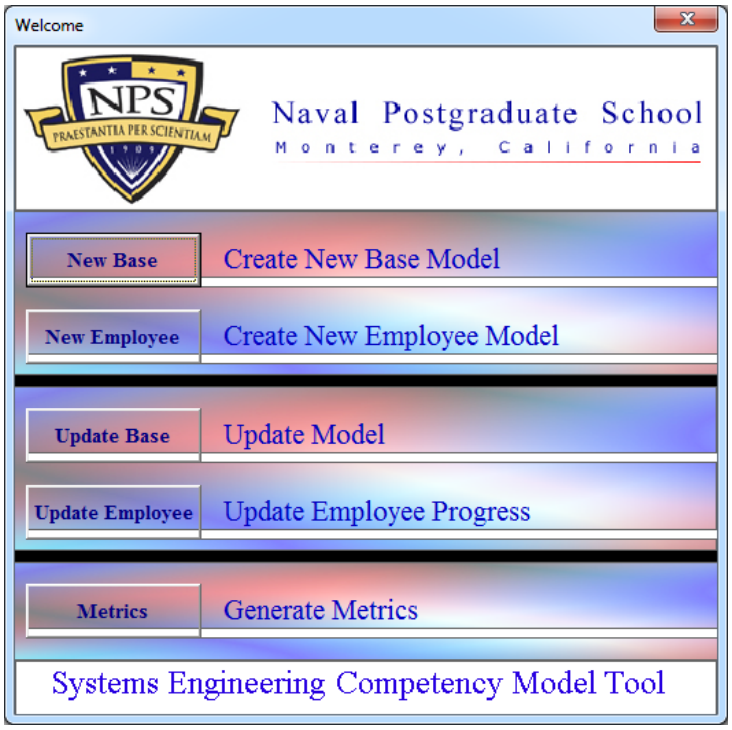

Figure 2. Welcome Menu

The "Create New Base Model" button initiates a wizard for creating a base competency model. The base model provides a list of competencies that can flow down from the organization level to the local level or simply be created at the local level. The model provides the ability to create new local competencies, develop proficiency levels for each competency, and then link them to a list of the OPM competencies. The base model is the local organization list of SE competencies that can be used to create job descriptions for managing employees within a single organization; therefore, the base model may contain more competencies than a standard employee model. The model currently only allows development using the bottom-up approach with either the organizational or local competencies and linking them up to the OPM competencies establishing traceability back to the OPM model. The traceability to the OPM competencies supports the development of job announcements compliant with the OPM hiring policies. An example of a base model is shown in Figure 3.

COMPETENCY LEVEL ASSESSMENT

Entry level ⟷ Journeyman level ⟷ Greybeard SME

Save | Close

Add New Competency

	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	OPM Core Comp.
SEP Development Remove Competency	DAU trained	Read at least SEPs	Written a section within a SEP	Written multiple sections within a SEP	Wrote a SEP	Wrote multiple SEPs	Technical Planning
Risk Management Remove Competency	DAU trainted	Read OSD Risk Guidance	Tracked a risk from genesis through mitigation plan	Developed section of a Risk Management Plan	Wrote Risk Management Plan and been through a Risk Review Board	Been Risk Leadand memeber of a Risk Review Board	Risk Management
Test Plan Development Remove Competency	DAU trainged	Read a Test Plan	Written a section within a Test Plan	Written multiple sections within a Test Plan	Wrote an entire Test Plan	Wrote multiple Test Plans	Verification, Validation

Note: Level accomplishment is indicated by simply highlighting the corresponding cell
Note: Each subsequent Level of accomplishment presumes accomplishment of every prior level descriptors

Figure 3. Example Competency Base Model

The base model in Figure 3 shows the local competency on the left and the corresponding OPM competency on the far right, which shows the linkage between them. The figure identifies the description required at each corresponding level of knowledge for each competency. The model provides additional descriptions when the mouse hovers over the buttons, including functional details on the operation of each button.

The "Create New Employee Model" button initiates a wizard for creating an employee model constructed from the base model. The employee model is a replication of the base model that is linked to that employee, but can also be tailored to the specific employee. The model supports the development and monitoring of employee progress for developing competency-specific knowledge. Figure 4 is an example of an employee competency management model. The blue-shaded cells represent the current state of competency knowledge for the employee. Additional controls, such as the example controls for an employee model shown in Figure 5, are embedded in the worksheet that allow the user to perform several functions for model management.

COMPETENCY LEVEL ASSESSMENT

Entry level ⟷ Journeyman level ⟷

Save / Close							
Add New Competency	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	OPM Core Comp.
Update Progress / SEP Development / Remove Competency	DAU trained	Read at least 2 SEPs	Written a section within a SEP	Written multiple sections within a SEP	Wrote a SEP	Wrote multiple SEPs	Technical Planning
Update Progress / Risk Management / Remove Competency	DAU trained	Read OSD Risk Guidance	Tracked a risk from genesis through mitigation plan	Developed sections of a Risk Management Plan	Wrote Risk Management Plan and been through a Risk Review Board	Been Risk Lead and member of Risk Reivew Board	Risk Management
Update Progress / Req Management / Remove Competency	DAU trained	Trained on DOORS	Written requirements for at least one program	Owner of a rerquirement section for a progrm	Written a Requirements Management Plan	Been the lead of Requirement Managent Plan for at least 2 programs	Requirement Management

Note: Level accomplishment is indicated by simply highlighting the corresponding cell
Note: Each subsequent Level of accomplishment presumes accomplishment of every prior level descriptors

Figure 4. Example Employee Competency Management Model

Figure 5. Example Employee Model Controls

The controls perform various standard functions such as saving the model, updating employee progress, and adding and removing competencies. The “Close” function closes the worksheet and restarts the tool welcome menu. The controls also provide the ability to add or remove competencies as the project evolves or the employee changes responsibilities. The “Update Progress” control advances the blue cells from left to right in order to indicate the current competency level and recycles once the end is reached. The “Update Model” button in Figure 2 updates the user selected model using controls similar to those shown in Figure 5. The controls in Figure 2 do not have the update progress as that is only available when in the employee model.

The “Update Employee Progress” button updates the employee model using the controls shown in Figure 6. The Update Employee Progress selection menu shown in Figure 6 provides the capability for exporting and importing the employee model once the employee is selected. The export capability allows the model to be provided to a subordinate organization for utilization or to the employee for updating relevant information in the model. The import capability allows the user to import the model once the update is complete. The export and import controls provide the ability to provide models for use by other organizations and to consolidate to models as necessary to maintain configuration control.

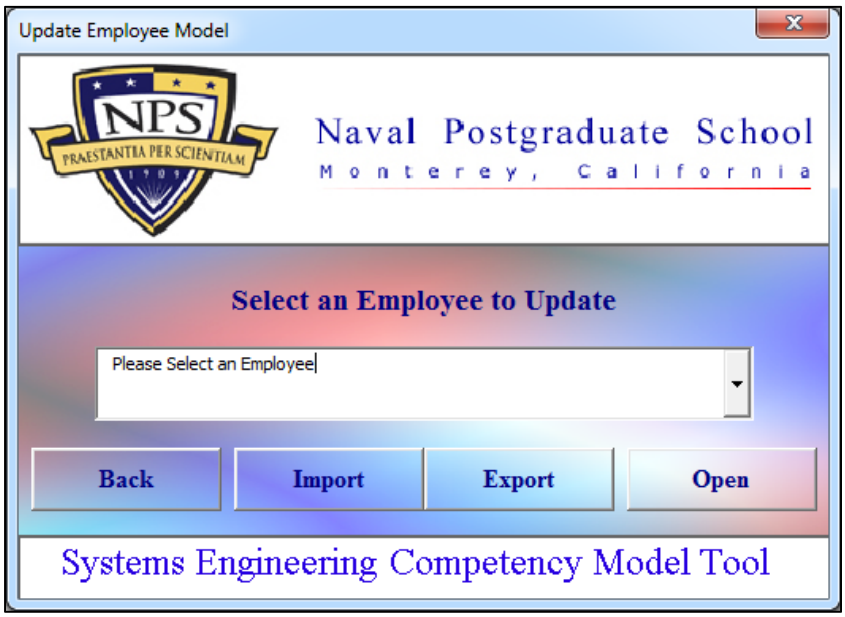

Figure 6. Update Employee Model

The tool provides a straightforward solution for creating competency models for use at the organizational or local level. The resulting models provide several important capabilities like identification of local competencies, assessing employee knowledge, identifying areas for focused training, and linking back to the OPM competencies. The next step is System Verification to verify the model with the stakeholders, presented in Chapter IV.

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IV. SYSTEM VERIFICATION

This chapter discusses the system verification process applied to the SECCM project. Topics covered include the verification methodology, the verification results, and improvements made to the Redstone SECCM Tool as a result of the verification process. This is the third and final step of the capstone project systems development process.

A. METHODOLOGY

The methodology used to verify user needs and requirements consisted of face-to-face meetings with the main stakeholders to provide a walkthrough of the Redstone SECCM Tool and its capabilities, and then a method to capture metrics for the tool through the use of survey questions. The NPS IRB determined that the survey questions did not constitute human subjects research. Any issues or recommended changes are addressed based on the feedback from the meetings and the survey metrics. Some requirements are beyond the scope of this capstone project. With requirements known and discussed, the capstone team developed objective product metrics that would be asked to the main stakeholders with the intention of assessing how well the Redstone SECCM Tool met the needs that were laid out earlier in the project process. The metrics used to evaluate the system had a scale rating of 1 to 5 with 5 being the most satisfied. The metrics included evaluation in the following areas:

- customer expectation
- likelihood to recommend to others
- overall satisfaction
- ease of use
- quality of help or user guide
- tailorability
- tool organization
- ability to meet stakeholder needs
- capability to help develop a training plan

Due to time constraints of the stakeholders, the capstone team demonstrated how the Redstone SECCM Tool was to be used by providing an example of how competency data is entered into the tool and displayed. The focus was on the bottom-up approach, which is defined as the method of creating a competency model by starting with defined local competencies and then tying them back to higher level Army competencies. Since most projects and organizations know the competencies required of their personnel, the bottom-up approach was the logical starting point for the tool. The capstone team demonstrated to the stakeholders how the Redstone SECCM Tool functions and how the supervisor can use the tool for personnel development and position descriptions, versus how the employee could use the tool to guide their career path. The demonstrations were consistent among stakeholders as to not skew the results. Due to time limitations, the stakeholders were not given a user guide prior to the initial demonstrations.

B. VERIFICATION RESULTS

The stakeholders were eager to see the results of the Redstone SECCM Tool development and each stakeholder felt more should be done to evaluate and assess system engineering competencies, so this tool concept was considered a step in the right direction. Three main stakeholders were used for the verification of the Redstone SECCM Tool due to their direct interest and expected usage after this capstone project is complete. A summary of each stakeholder's assessment is provided in the following paragraphs. For anonymity, the names Stakeholder 1, Stakeholder 2, and Stakeholder 3 will be used in this report.

1. Stakeholder 1

During the first verification event, the capstone team described the project problem and how the Redstone SECCM Tool was designed to help solve that problem. The verification event included a demonstration of the tool; unfortunately, there were some minor technical difficulties, but the overall goals of the tool were on display.

a. Stakeholder 1 Observations

- The stakeholder was more interested in how this could be used in hiring and promotion than in personnel tracking.
- The stakeholder wanted to understand how an employee has progressed over time. History and progression were also major factors.
- The stakeholder requested a notes column.

Running through this effort demonstrated the importance of the top-down method. If AMRDEC-defined competencies existed, it would be easy to flow these down to organizations and divisions.

b. Stakeholder 1 Recommendations

- Pre-populated level fields
- Ability to compare two (or more) employees graphically
- More reporting options
- Printable version of employee fields
- Historical progression

The use of competencies during mid-career planning seems to be underutilized among organizations and employees. The Redstone SECCM Tool is designed to assist in career planning and many of the recommendations above would aide in that endeavor.

2. Stakeholder 2

Stakeholder 2 was not able to attend the In-Process Review #2 so the stakeholder was unfamiliar with the progress of the tool and its capabilities to this point. During initial discussions the capstone team explained that the tool is a “framework” for entering the desired competencies determined by the user, not that there is a default set of detailed competencies or library function currently embedded in the tool. The capstone team explained that every user will likely have a different purpose and likely a different set of competencies considered of value.

a. Stakeholder 2 Observations

- Entering the competencies allowed the user flexibility and adaptability of use, which the stakeholder found useful.
- Stakeholder believed traceability to the 44 OPM competencies was a useful capability provided by the tool.

b. Stakeholder 2 Recommendations

- Provided positive feedback.
- Felt the tool could be useful for existing projects.
- Requested a copy of the Redstone SECCM Tool for further evaluation. The user guide was not available at the time of the interview, so it could not be utilized or reviewed during the interview.

3. Stakeholder 3

Stakeholder 3 was familiar with the Redstone SECCM Tool basics, as a similar tool is used in that office for employee assessment and training needs. Because Stakeholder 3 participated in the In-Process Review #2, the stakeholder was familiar with the capstone project scope and tool progress to date.

a. Stakeholder 3 Observations

- Indicated a desire to use the tool more within the management and team role versus at the employee role.
- Indicated tool was geared toward individual usage, but not designed for collection of summary competency data to be displayed graphically.

b. Stakeholder 3 Recommendations

- Recommended that the tool include a summary roll-up to be used by the manager to demonstrate organizational effectiveness, and to determine if skill sets are growing or eroding over a period of time
- Noted that it was important for the tool to be used as dialogue between employee and management, and that it should not be used for performance ratings or promotions.

Presented in Table 14 are the results from the tool assessment performed by the stakeholders, which indicate that the original requirements (shown in Table 7) have been

satisfied. All users scored the tool with a three or higher in every category. Following completion of the tool and user guide, each stakeholder requested a chance to perform a follow-up review in order to reevaluate the criteria that was marked to be determined (TBD).

Table 14. Tool Assessment Summary

Product Metric (1-5, with 5 most satisfied)	**Stakeholder 1**	**Stakeholder 2**	**Stakeholder 3**
Customer Expectations	5	5	3
Likelihood to recommend to others	4	TBD	3
Overall Satisfaction	4	5	3
Ease of use	5	5	5
Quality of help or user guide	TBD	TBD	TBD
Tailorability	5	5	5
Tool organization	4	TBD	5
Meet the need	3	TBD	4
Help develop a training plan	4	3	4

Based on the feedback received from the users, a list of modifications was documented for future application. Not all enhancements could be made due to academic time constraints to complete the project, but these other enhancements are documented as future considerations that are recommended to be made in any future tool developments.

C. MODIFICATIONS TO REDSTONE SECCM DEVELOPMENT TOOL

Each stakeholder had a demonstration of the Redstone SECCM Tool via the verification process. Along with the tool assessment survey, valuable feedback was received from each stakeholder on further modifications to the tool that could make it

more beneficial to their divisions. The potential modifications as functions per the stakeholder feedback were as follows:

- Output necessary information for job descriptions/announcements.
- Assign a value of “Required at Entry” for specific competencies.
- Assign a value of “Importance” for specific competencies.
- Perform top-down competency development.
- Assign weighting factors for each competency.
- Track domain expertise for each competency (e.g. RAM, Failure Modes Effects and Criticality Analysis [FMECA], Missiles).
- Add a “Notes” column within the competency model view.
- Trace specific competencies or proficiency levels to rank/grade.
- Output model into a printable report.
- Create different types of graphical views of competencies and of employee progression.

However, due to the constrained time line of the capstone project, the team had to decide which ones could actually be developed and integrated. The two major factors for this decision were development and integration timeline, as well as which capability provided benefit to the most stakeholders. Considering these two factors, the capstone team was able to include limited graphical view capability to the tool. Only two types of graphical views are currently available within the tool. The “Generate Metrics” button generates knowledge-level metrics for employee(s) depending on which metric type is selected from the menu shown in Figure 7. The metrics have two types: generating graphics for a single employee or generating graphics for all the employees with models in the spreadsheet. Results for the Employee Status example for a single employee are shown in Figure 7. The Competency Summary Rollup generates model specific metrics for all employees, with example results shown in Figure 8. The metric outputs can be sent to Microsoft PowerPoint for further development. “Generate Metrics” requires that the employee models be created using the correct base model and have progress completed before metrics can be generated.

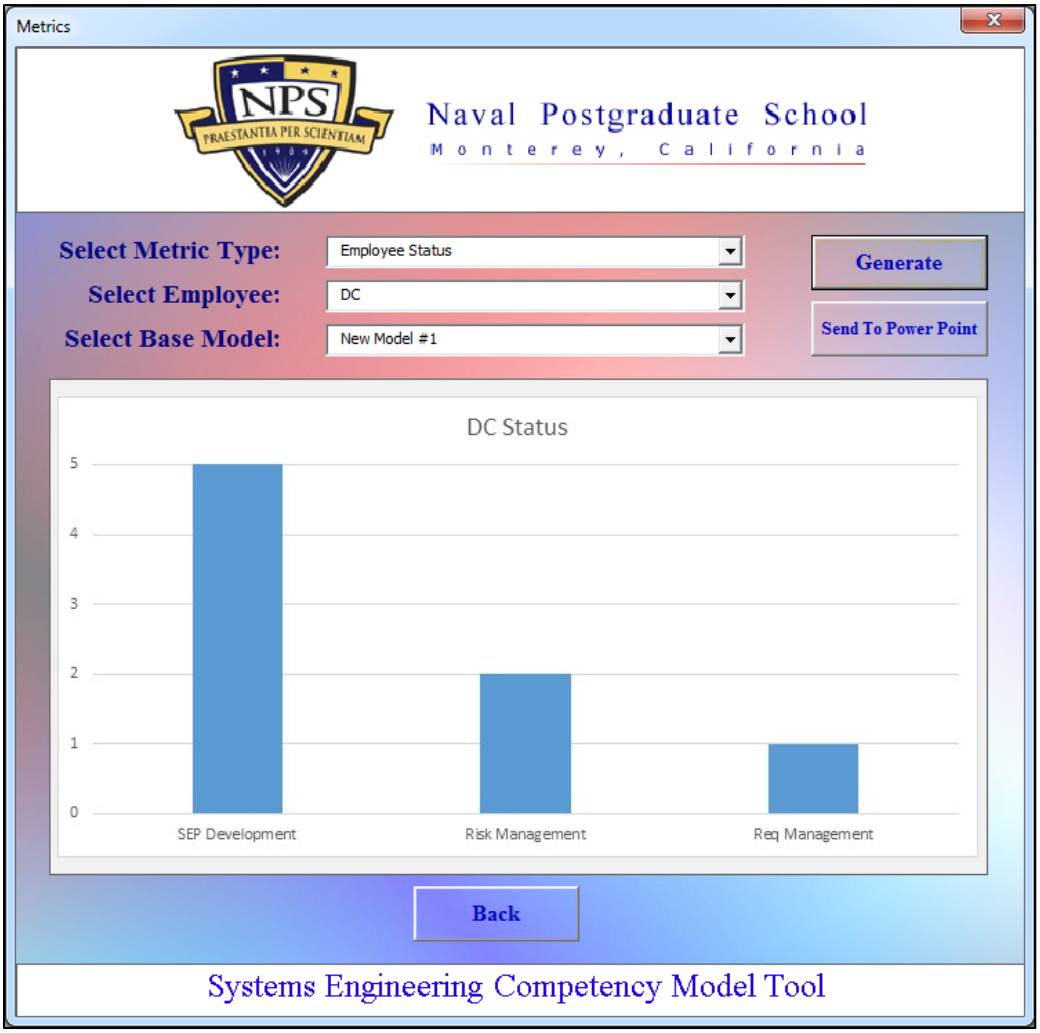

Figure 7. Example Employee Status

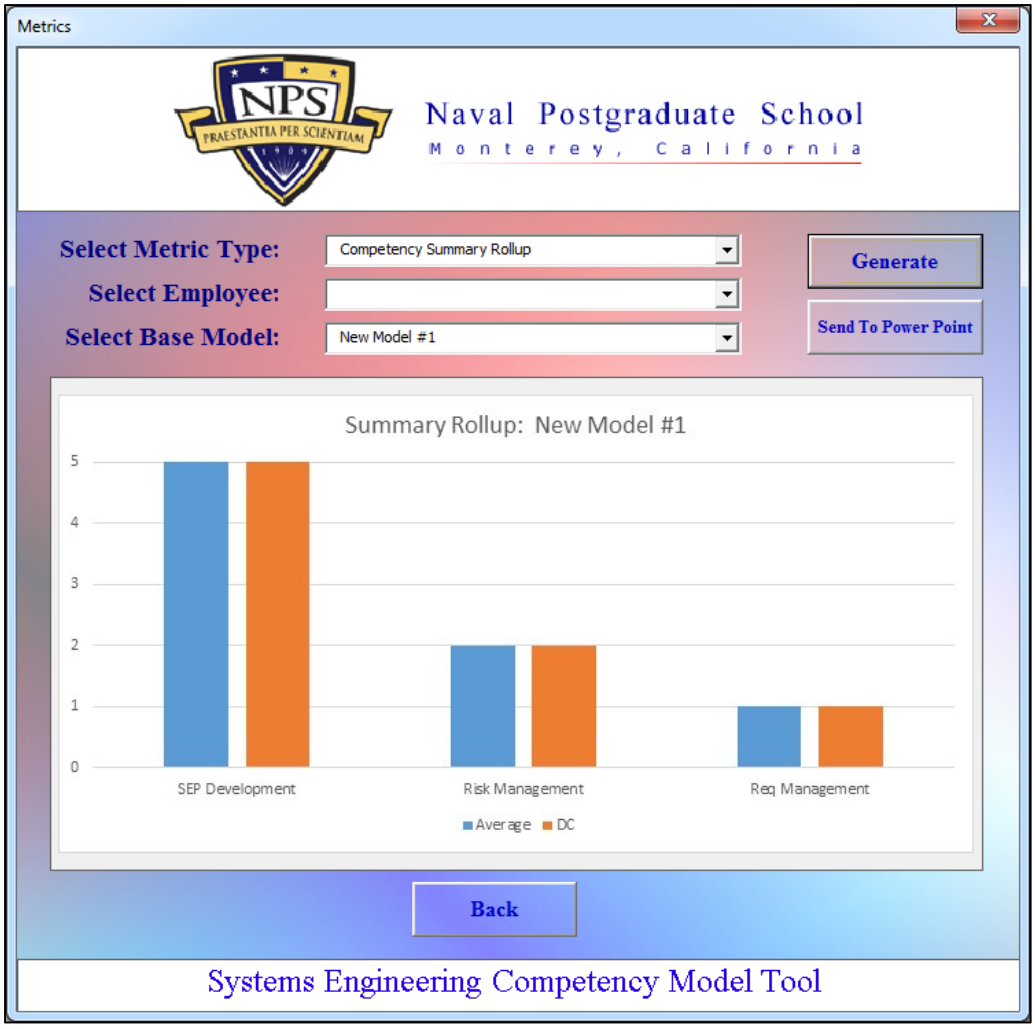

Figure 8. Example Summary Rollup Metrics

While the current schedule constrained further development of more graphical displays, the baseline architecture was built. Development time was spent to develop the architecture to properly store model data. With this architecture in place, development time for additional graphical views is minimized.

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The capstone project for utilizing the OPM SECCM and developing a competency model solution for the AMRDEC stakeholders yielded several results. The initial expectations from the project problem statement changed throughout the initial user needs analysis and system development. The original project was intended to be the application of the SECCM at the organizational level with the focus revolving around the creation of an SE job series or the creation of the associated training requirement for the job series. The resultant product of a Redstone SECCM Tool User Guide and Redstone SECCM Tool fulfills the need as defined in the problem statement.

A. SUMMARY

The project began with the OPM SECCM model and resulted in a competency model tool for addressing the needs as defined by the focused stakeholders group. The identification of stakeholders proved to be challenging and originally started with representatives from AMC, MDA, PEO M&S, and AMRDEC. The capstone team made the decision to concentrate on the three AMRDEC stakeholders due to the inconsistent stakeholder availability of the other organizations. As the capstone team members were employees of the AMRDEC, it presented an opportunity to focus the project on a common organization.

The capstone project utilized the HCD methods throughout the SE process approach. The HCD approach makes the involvement of the stakeholders an essential part of the development process to drive the design toward the solution that met the stakeholders' needs. The needs analysis process results indicated the current state of the SE career field definition at the AMRDEC to be ill-defined and inconsistently applied across different organizations. The needs derived from this analysis were developed using the stakeholder viewpoints and user personas resulting in seven stakeholder needs.

The capstone team analyzed the needs to develop the associated stakeholder requirements. It was at this point that the needs evaluation identified specific needs that meet the intent of the project scope. The primary scope driver for the project was the

limited timeline of three academic quarters to complete the project while meeting the capstone team's goal of producing a result that met the stakeholder's needs. Based on team discussion and the identified constraints, the project was reduced from the seven identified needs down to two needs that would become the focus of the requirements analysis. The remaining five needs identified in Tables 6 and 7 were determined to be out of scope for this project. The two needs were decomposed into six requirements that were used to drive design alternatives during the design phase. The design solution chosen by the capstone team was evaluated against these requirements during the verification phase.

The design phase took the requirements and developed characteristics and enablers for brainstorming design alternatives for selection and resulted in four design alternatives. The AoA evaluation was accomplished by using the AHP for analytically comparing the four design alternatives. The analysis determined that the two best options were the Redstone SECCM Tool and Redstone SECCM Tool User Guide. The Redstone SECCM Tool provides a semi-automated tool to develop local competencies for an organization, and optionally for individual personnel, traceable back to the OPM SECCM model. The User Guide is a document that describes how to use the Redstone SECCM Tool to develop the local and user competency models. The decision to combine the Redstone SECCM Tool and the Redstone SECCM Tool User Guide improved the ability of the users to better understand the Redstone SECCM Tool and offers suggestions on how to apply the resulting models, thereby further improving the solution integration. Combining the tool with the user guide alleviated some of the original stakeholder concerns about the complexity and vagueness of the OPM model and met the needs of the user more effectively than either could alone.

The system verification technical process establishes traceability of the design solution back to the stakeholder requirements. The Redstone SECCM Tool and Redstone SECCM Tool User Guide verification consisted of providing a beta version of the products for stakeholder evaluation. Due to schedule constraints, the initial stakeholder evaluation of the Redstone SECCM Tool did not include the Redstone SECCM Tool User Guide as part of the evaluation. The updated Redstone SECCM Tool and Redstone SECCM Tool User Guide will be provided for an extended stakeholder evaluation once

the initial comments are incorporated. The three primary stakeholders evaluated the Redstone SECCM Tool using metrics traceable to the stakeholder requirements to determine stakeholder acceptance. The initial feedback resulted in scores for the Redstone SECCM Tool that indicated that requirements were met. The three primary stakeholders provided input for follow-on tool development.

B. CONCLUSIONS

The main conclusion is that there is a significant user need for a product like that of the Redstone SECCM Tool. The capstone team found an overarching need for identifying competencies, determining knowledge level, and documenting the deficiencies within the AMRDEC SE workforce. The stakeholders consistently commented that the Redstone SECCM Tool provided an effective framework for developing these models and identifying deficiencies. The tool also provides linkage back to the OPM SECCM model competencies, supporting the ability to produce the job descriptions and announcements for hiring skilled systems engineers. Overall, the end products were well received.

The stakeholders almost unanimously agreed that the OPM model was too broad and too vague and encompassed too many competencies to be effective. Upon further investigation into the OPM competencies, it was determined that more than a few were applicable to more than just systems engineers. For example, many members in the workforce beyond systems engineers need competencies like acquisition and configuration management, to name a few. This was a driver in the design criteria for the product with the resulting Redstone SECCM Tool having all the OPM model competencies available but is tailorable to only those applicable to the local organization. That was important for the stakeholders, allowing local organizations to identify only those competencies specific to their programs and track progress against them. The additional benefit of providing the linkage to the OPM competencies made the ability to produce job descriptions and announcements compliant with the OPM policies much easier.

A third finding from the project was that the stakeholders recognized the need for identifying local competencies and tracking the knowledge growth of their employees. Several stakeholders expressed the need for comparing employees to assess the organization knowledge gaps and overall growth. All three primary stakeholders needed to effectively track the organization knowledge growth but internally developed three different metrics. One stakeholder expressed an overall need to assess the individual knowledge gaps so that effective training plans could be created to address those gaps. Another stakeholder expressed the need for demonstrating the progression of organizational knowledge over time, which characterizes the broad knowledge status as the organization grows and changes. The final stakeholder was focused on how the tool could assist in hiring and promoting. The differences seen in only three stakeholders highlight the range of competency model usage and emphasizes the challenges associated with implementation of a single approach for SE within the DOD. Additional stakeholder insights would help place a greater emphasis on identifying and defining the comparable SE competencies across the DOD.

The needs analysis effort presented a clear picture of the current state of SE and how it is just starting to solidify with AMRDEC local organizations. This is potentially due to limited detailed guidance from DOD on SE and the learning curve associated with how to apply SE at the local levels. In the absence of additional details, organizations have started to implement SE concepts and principals within their organizations to differing degrees. Systems engineering consists of widely varying roles from the systems engineer who is expected to be the system subject matter expert to being system technical integrator. These differing roles may produce confusion within the SE community, limiting the ability for the movement needed to expose them to different aspects of SE that in turn limits career growth. This project provides the initial step of creating a framework for creating local competencies traceable back to the OPM model within a highly flexible tool. The Redstone SECCM Tool provides the linkage of the OPM competencies to the local organizations competencies. The Redstone SECCM Tool fills the gaps identified by the stakeholders during the early project analysis while providing

the traceability back to the OPM model establishing the initial step for developing the DOD SE workforce.

Overall the Redstone SECCM Tool was a success as identified by the stakeholders and represented by the high metric scores. As the project concluded, the stakeholders expressed considerable appreciation for how well the tool solved the underlying need of developing organization's competencies and tracking employee progress against them. The capstone team was surprised how well the tool was accepted and the comments about how they planned on using it for supporting their organizations in different ways. The resulting tool usage is expected to be developing organization competency models and supporting the organizations in recruiting and developing existing systems engineers using the model data.

C. RECOMMENDATIONS

The Redstone SECCM Tool was developed as a prototype with the intention of applying the OPM Army SECCM at the organizational level. The limited time to develop requirements, assess design alternatives, and develop and verify the Redstone SECCM Tool meant that some of the capabilities that would be beneficial in the tool had to be left out for future revisions. Additionally, as stakeholders and other potential users within the target organization began to see the utility of the Redstone SECCM Tool, other secondary capabilities were requested to assist the user track and manage competency models for the organization and personnel. This section summarizes most of these capability additions for future consideration. Each recommendation is presented along with a brief description; no weighting or ranking are given to any of the recommended changes, as the goal was to summarize all future capabilities desired.

1. Recommendation: Job Description and Announcement Output

The user requested the capability to output necessary information for job descriptions or announcements. One of the benefits of the Redstone SECCM Tool is that it links local competencies for a given position to the OPM Competency Model used in USA Staffing to create job announcements. The capability to take an existing model and easily output the necessary information for USA Staffing to create a job announcement

would streamline the data creation process for hiring managers, reduce errors, and provide more consistency.

2. Recommendation: "Required at Entry" Competency Discriminator

The stakeholders requested the capability to assign a value of "Required at Entry" for specific competencies. This capability would provide prospective systems engineers with insight into the necessary competencies before applying for a position. This ties back to the USA Staffing job announcement creation process as well.

3. Recommendation: Discriminator for More "Important" Competencies

Similar to the "Required at Entry" recommendation, the stakeholders would like to assign a value of "Important" to specific competencies. Some local competencies can link to multiple OPM competencies. By allowing specific OPM competencies to be more important to a local competency, this would streamline the job hiring and announcement process with USA Staffing and add a layer of clarity when many competencies are selected.

4. Recommendation: Top-Down Approach for Competency Model Development

The top-down competency development would include all local competencies within an organization in a drop-down box as well as built-in linkage between OPM competencies and local competencies. The Redstone SECCM Tool was originally envisioned to contain both a top-down development capability as well as a bottom-up capability, but the top-down capability was determined to be too time consuming for the effort. The top-down development capability would require a database of all existing local competencies from which to select on new competency models. This was not feasible given the timeframe of the effort and the size and footprint of the organization. Additionally, each local competency should already be linked to the OPM competencies to reduce the burden on each new competency model that is developed.

5. Recommendation: Weighting Factors

One stakeholder recommended a method to weigh competencies against each other, to add an additional layer of objectivity to the model. This would benefit more in the hiring process than in employee development. This would also give the organization an opportunity to develop critical competencies within the organization. Along with the "Important" competency discriminator, this demonstrates that the stakeholders are interested in which competencies are most important both to the organization as well as to the employee.

6. Recommendation: Domain Experience Tracking

One stakeholder requested the capability to track domain experience for each competency (e.g., RAM, FMECA, Missiles). Within DOD, there are multiple domains of experiential knowledge that are gained depending on the product type. Some situations may be easier than others to translate skills between product types. The ability to track not only a competency but also the domain or domains in which proficiency is gained would be a valuable addition to the Redstone SECCM Tool.

7. Recommendation: Notes Column

As employees are given opportunities to further their advancement in a particular competency, it would be beneficial to take notes within the tool based on training taken, goals, or other administrative items that would not be shown within the tool already.

8. Recommendation: Trace Competency to Rank or Role

All stakeholders recommended that the tool be able to trace specific competencies or proficiency level to rank or grade. One in particular wanted to see roles and jobs being tracked to competencies, such as Chief Engineer. One key difference between the OPM SECCM Report and the Redstone SECCM Tool is the ability to trace specific competencies to grades. This was a challenge to implement into the Redstone SECCM Tool and was ultimately dropped in favor of an easier interface. Multiple stakeholders noted that it would be beneficial for employees to understand what key competencies are missing in order achieve a specific position such as Chief Engineer or Technical Lead.

Both of these could be added to the tool with careful changes to the proficiency development of the tool.

9. Recommendation: Printable Report

Although the tool was considered user-friendly, there was an appetite among the stakeholders to output the information into a printable report that could be presented to a higher authority. Excel must be formatted to print in a printer-friendly format. No such format exists within the tool.

10. Recommendation: Employee Historical Progression

In order to track the career progression of an employee over a long period of time, there must be a built-in capability to view past competency reports and see the progression over time of each competency. This would require a form of record keeping. A database system would most likely be the easiest way to implement this capability, with the tool sending reports into the database annually.

11. Recommendation: Additional Graphing Capability

The users were satisfied with the upgraded graphics capability, but there were other desired graphing options still missing. Currently, one may not manipulate the only type of graphics available. Each user may have a different preference on how the graphics are displayed or filtered, and the ability to modify the graphics would aid the user in the creating a view that works best for the situation. One potential use of this is to show all employees along with associated competency models, while hiding personal information such as names.

APPENDIX: NEEDS ANALYSIS RESULTS

NEEDS ANALYSIS RESULTS TABLES

Table 15. Primary Stakeholder Quotes

Stakeholder	Quotes
AMRDEC ED:	"Competencies are not binary," "Competencies should be based on experience," "9 competencies work for us," "Competencies should be locally managed."
PEO M&S 1:	"Experience gained through multiple job rotations is the most important"
PEO M&S 2:	"Competency model could be useful however I would invert the rows and columns and locally define the needed competencies."
PEO M&S 3:	"On the job experience trumps competency models with breadth and depth of knowledge important."
AMRDEC SED:	"A real competency model must be like any model: It must be prescriptive, must meet the needs of the organization, must yield quantitative results, must be verifiable/quantifiable, and subject to continues improvement."
AMRDEC WDI:	"Experience depth first, before you get breadth," "Understand the entire life cycle," "define level of experience by grade," "locally managed competency models"
PEO M&S 4:	"Up front is most important," "Need an SE degree," "Institutional training," "All program offices act differently"
CP-16:	"Competency model is a good idea but implementation will be problematic," "Existing systems engineers may not meet the new requirements."
MDA:	"44 competencies are too many," "Systems engineers are not well defined, should focus on requirements"

Table 16. Stakeholder Empathy maps

Stakeholder	Feeling Toward Competency Model (higher is more positive)	Think and Feel
AMRDEC ED:	5	Multi-level competencies, experience based competencies, locally managed competencies, small number of competencies
PEO M&S 1:	4	experience based competencies
PEO M&S 2:	2	locally managed competencies
PEO M&S 3:	5	experience based competencies
AMRDEC SED:	5	locally managed competencies, experience based competencies
AMRDEC WDI:	4	locally managed competencies, experience based competencies
PEO M&S 4:	3	locally managed competencies
CP-16:	3	N/A
MDA:	3	small number of competencies

Table 17. Stakeholder Personas

Persona	Stakeholder
SE is any engineer that works on a system	AMRDEC WDI
	PEO M&S 1
	PEO M&S 2
	AMRDEC SED
SE does work as defined in INCOSE HB	AMRDEC ED
	PEO M&S 3
	PEO M&S 4
SE is requirements focused	MDA
No opinion/Impartial	CP-16

CANDIDATE QUESTIONS FOR SECCM CAPSTONE PROJECT

Specific for Capstone Stakeholders:

At the Organization Level

1. Describe the Systems Engineering career field as seen by your organization. What are the roles of the Systems Engineers within your organization?

2. What guidelines or criteria are used within your organization for hiring Systems Engineers (entry, mid-level, senior, and lead positions)? What guidelines or criteria are used for creating job descriptions for hiring Systems Engineers?

3. In hiring a systems engineer, is depth of knowledge in a particular competency or breadth of understanding across all competencies prioritized? If depth of knowledge is prioritized, which competencies does this apply for your organization?

4. Is a Systems Engineering competency model currently applied in your organization, and if so, how is it used? What model is used?

5. How would having a DOD promulgated Systems Engineering Competency Model help the manager/hiring manager? What gaps still exist? What changes would help your organization?

6. Would having a defined occupational series for Systems Engineering benefit the DOD as a whole, and if so, please explain how? From your organizational perspective, what are the potential downsides of a DOD Systems Engineering occupational series if implemented?

7. Out of the 44 Critical Competencies, are there any that are unique to Systems Engineering only for the Army?

8. Which of the 44 Critical Competencies stand out as most important for a Systems Engineer and why? Are there any natural groupings within those competencies?

9. Is the Army Systems Engineering Competency Model missing any critical competencies? If so, what are they?

10. Do Systems Engineers across the Army lack any competencies necessary to perform the role of systems engineering? If so, what are they?

11. What percentage of work time does the average Systems Engineer spend doing technical work rather than programmatic or managerial work, at the Entry level (GS-7 through GS-11), Journeyman level (GS-12, GS-13), GS-14, and GS-15 levels?

12. Imagine for a minute that the SE Competencies were organized into a pyramid with “Required at Entry” competencies on the bottom and the highest-level competencies on top. What different levels would be in this pyramid? Would this product help in defining the position description at multiple grade levels [Entry level (GS-7 through GS-11), Journeyman level (GS-12, GS-13), GS-14, and GS-15 levels] within your organization?

13. Suppose a team of 4 Systems Engineers is proposed to work cooperatively on a project. Describe how their abilities, skillsets, or competencies would preferably differ and align. Now given the competencies in Table 21 of the Army Occupational Survey, group the competencies that best represent the differing skillsets of the 4 Systems Engineers as desired.

SUPPLEMENTALS

The following products are packaged with this report or may be obtained by contacting the Dudley Knox Library at the Naval Postgraduate School.

A. REDSTONE SYSTEM ENGINEERING CAREER COMPETENCY MODEL TOOL

A Microsoft Excel–based systems engineer career competency model tool, named Redstone SECCM Tool, assists and promotes the creation of, and tracking of, an individual or organizational competency model. The tool provides a wizard-based, user-friendly interface for creating competency models that are intended to be traceable back to the OPM SECCM competencies. The tool provides flexibility by allowing the user to either generate organizational models for dissemination or develop employee competency models. The employee models can be used within the local organizations for developing training plans

B. REDSTONE SYSTEM ENGINEERING CAREER COMPETENCY MODEL TOOL USER GUIDE

This user guide is an instruction for using the Redstone Systems Engineering Career Competency Model Tool (Redstone SECCM Tool) developed and managed by systems engineering students at the Naval Postgraduate School. Although this guide is intended to guide the development of a competency model within a specific tool, many of the steps and procedures can be applied to any general competency model development effort, regardless of tool used.

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